Anatomic study of the dorsalis pedis artery, first metatarsal artery, and second metatarsal bone for mandibular reconstruction

Jae-Won Kim, D.D.S., M.S.

Department of Dentistry
The Graduate School, Yonsei University

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Directed by Professor Kyung-Seok Hu, D.D.S., Ph.D.

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Jae-Won Kim

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This certifies that the Doctoral Dissertation of Jae-Won Kim is approved.

허 경 석

Thesis Supervisor : **Prof. Kyung-Seok Hu**

Heejin Kim

Thesis Committee Member : **Prof. Hee-Jin Kim**

Thesis Committee Member : **Prof. Hyung-Jun Kim**

Thesis Committee Member : **Prof. Mi-Sun Hur**

Thesis Committee Member : **Prof. Hun-Mu Yang**

The Graduate School
Yonsei University

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본 논문이 완성되기까지 세심한 지도와 아낌없는 격려를 해주신 지도교수 허 경석 교수님께 깊은 감사를 드립니다. 또한 바쁘신 와중에도 많이 지도해 주신 김 희진 교수님, 김 형준 교수님, 허 미선 교수님께도 깊은 감사 말씀 드립니다.

또한 본 연구를 도와주신 해부학교실 조교선생님들께도 감사의 마음을 전합니다. 특히 이 형진 선생님, 최 유진 선생님, 이 규호 선생님께 깊이 감사드립니다. 또한 통계와 분석을 도와주신 정 회인 선생님, 이 채은 선생님께도 감사드립니다.

또한 제가 연세대학교 해부학교실에 들어와서 아낌없이 학문적 임상적 교류를 할수 있게 하였고, 군 훈련 받을때 만나 같이 봉사활동을 한 인연이 여기까지 결실을 맺을수 있게 아낌없이 도와주신 양 헌무 교수님께도 진심을 담아 감사드립니다.

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2014년 12월

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Anatomic study of the dorsalis pedis artery, first metatarsal artery, and second metatarsal bone for mandibular reconstruction

Jae-Won Kim D.D.S., M.S.

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The Graduate School, Yonsei University

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The dorsalis pedis flap is currently widely used for its versatility and efficiency. A full understanding of the anatomic position of the dorsalis pedis artery and its continuity to the first metatarsal artery is crucial for the success and survival of the flap. However, the anatomy of the dorsalis pedis and first metatarsal arteries varies greatly between individuals. It is also possible to form osteocutaneous flaps from dorsalis pedis flaps, but thus far no studies have investigated their anatomic form and the trabecular: cortical bone ratio (TBR). The purpose of this study was to clarify the anatomic variation of the dorsalis pedis and first metatarsal arteries by cadaver dissection, and to define the TBR of the second metatarsal bone to ascertain their suitability for implants.

Fifty-two specimens were prepared for this study. Each of the specimens was dissected on the dorsal side of the foot to search for the dorsalis pedis artery. The foot was then cut on the coronal side, and the second, third, and fourth metatarsal bones were removed to reveal the path of the first metatarsal artery in relation to first dorsal interosseous muscle. The second metatarsal bone was then cut on five sides and scanned with a photograph scanner, and the TBR was calculated using image analysis software. The data were analyzed statistically using ANOVA and paired t-tests.

Three types of the dorsalis pedis artery were found: (1) type A was the most common (94.1%), in which the artery continuously formed the first metatarsal artery, (2) the next was type C (3.9%), in which the artery ran below the first dorsal interosseous muscle, without revealing the first metatarsal artery on the superficial side, and (3) in type B (1.9%), the artery ran from the lateral side. Five variations of the first metatarsal artery were identified: Ia-c, and IIa and b. The most common was type IIb (30%), in which the artery ran below the first dorsal interosseous muscle, followed by type Ib (22%), in which the artery ran obliquely through the muscle, and type Ic (22%), in which the artery ran parallel to the muscle, IIa (18%), in which the artery ran above and below the muscle, and type Ia (8%), in which the artery only ran above the muscle. The second metatarsal bone was divided into five parts (1-5), and the TBR was calculated in all parts. There was no trabecular bone in regions 1 and 5, which were 10 mm from the edges of the base and head, respectively, in any of the specimens. The TBR appeared to be lower in region 3 (which was the middle of the body) than in regions 2 and 4, and highest in region 2; however, the differences were not statistically significant ($P>0.05$). All regions of the second metatarsal bone appear to be suitable for implants, but when placing the implant in the proximal end, care should be taken not to overheat the bone and to be wary of perforation when placing it on the middle side.

Key words : Dorsalis pedis artery, First metatarsal artery, First metatarsal bone, First dorsal interosseous muscle, Trabecular bone ration, Implant surgery.

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I . INTRODUCTION

The dorsalis pedis flap is currently one of the most diversely used flaps for reconstruction of oromandibular defects. It can be used as either a free flap or a free and osteocutaneous flap, which includes second metatarsal bone. It is thin and, hairless, but cannot be used for skin defects that exceed 10 cm 14 cm or bony defects of more than 8 cm (Ko et al. 2004).

In adults, the second metatarsal bone can be 5 – 8 cm long and can be used for marginal mandibular bone defects, particularly in the anterior mandibular arch (Azevedo et al. 2010). Not only is preservation of the dorsalis pedis artery crucial for flap survival, but also the first dorsal metatarsal artery plays an important role for osteocutaneous flaps, because it supplies the periosteum surrounding the second metatarsal and its proximal and distal cortical branches (Zuker et al. 1986). This flap has been largely neglected in reconstructive surgery, despite its versatility and efficiency. Success of this flap crucially requires an effective method of locating the dorsalis pedis and first metatarsal arteries. Doppler sonography, digital subtraction angiography, and magnetic resonance angiography can be used to confirm their locations (Kim et al. 2011). For Koreans, several studies have reviewed the course of these arteries in Koreans using Gilbert's classifications (Kim et al. 2011; Nam et al. 1994; Tark et al. 1996).

The second metatarsal bone can be used for the reconstruction of marginal mandibular body, or ramus defects. However, this bone has not yet been studied extensively, particularly regarding its suitability for implants, for which an adequate graft bone trabecular: cortical bone ratio (TBR) is needed. The purposes of this study were to: (1) Identify the surface anatomy of the course of the dorsalis pedis artery, (2) define the types of the metatarsal artery according to its relationship with the first dorsal interosseous muscle, and (3) clarify the anatomic characteristics of the second metatarsal bone and its suitability for mandibular implants by measuring its TBR.

Ⅱ. MATERIALS & METHODS

1. Materials

Twenty-six Korean cadavers were prepared for dissection; 2 specimens (i.e., left and right) were dissected in each specimen, giving a total of 52 specimens. The subjects comprised 16 males (mean age, 71.94 years; range, 48-96 years) and 10 females (mean age, 80.6 years; range, 67-96 years). Damaged specimens were not included in the study, so that ultimately 51 and 50 specimens were used to study the dorsalis pedis and first metatarsal arteries, respectively.

2. Methods

First, a superficial incision was made along the medial and lateral malleolus to expose the inferior extensor retinaculum. This incision was extended to the head of first metatarsal bone and to the fifth metatarsal bone. After locating the extensor hallucis longus tendon, it was cut at the joint of the first metatarsal and the first proximal phalanx, and reflected. The extensor hallucis brevis was then located and also cut at the same junction, and reflected. The dissection was continued to reach the first dorsal metatarsal artery. After dissection to examine the first metatarsal artery, the dorsal metatarsal ligaments, interosseous muscles, and metatarsophalangeal joint capsules were reflected and the second metatarsal bone was removed for study. After removal of all of the metatarsal bones, the dissection continued to study the anatomic variations of the first metatarsal artery in relation to the first dorsal interosseous muscle. All of the specimens of metatarsal bones, were cleaned of soft tissues using a periosteal elevator, and then fixed in 10% neutralized buffered formalin. Damaged specimens were not included in this study. The bones were measured using calipers and were sectioned at five separate locations (1cm below the edges of the head and base, from the middle point of the shaft, and 1 distant from the middle point on both sides) and were scanned using a photograph scanner (Perfection 3490, Epson). After obtaining all sectional images, the trabecular and cortical portions of the bones were measured using image analysis software (I-solution, iMTechnology, Coquitlam, Canada). The results were analyzed statistically using Microsoft Office Excel (Microsoft, Redmond, WA, USA). The data were presented in the tables as mean and SD values, and differences were tested for significance using ANOVA and t-test (95% confidence interval, $P<0.05$).

Ⅲ. RESULTS

1. The dorsalis pedis artery

The course of the dorsalis pedis artery could be categorized into three types (Fig. 1): (1) type A was designated if the dorsalis pedis artery ran to the medial one-third side of the foot from the point of the medial and lateral malleolus, and continuously formed the dorsalis pedis artery (Figs. 2, 3), (2) type B was designated if the artery ran to the lateral one-third side of the foot and continuously formed the dorsalis pedis artery (Fig. 4), and (3) type C was designated if the artery ran along the medial or middle one-third at the point of the malleolus and its course continued below the first dorsal interosseous muscle (Fig. 5). Type A was the most common of the three (48/51 specimens, 94.1%), followed by type C (2/51 specimens, 3.9%) and type B (1/51 specimens, 1.9%).

2. The first dorsal metatarsal artery

The course of the first dorsal metatarsal artery could be initially dichotomized (into types I and II) and then categorized into five subtypes (Fig. 6). Type I could be subdivided into types Ia, Ib, and Ic. Type Ia first dorsal metatarsal arteries ran above the first dorsal interosseous muscle (Fig. 7), type Ib ran through the muscle obliquely (Fig. 8), and type Ic ran through the muscle in parallel with its fibers (Fig. 9). Type II could be subdivided into type IIa and IIb. Type IIa first dorsal metatarsal arteries ran both above and below the muscle (Fig. 10), while type IIb ran below the muscle (Fig. 11). The most common type of first dorsal metatarsal arteries was type IIb (15/50 specimens, 30%), and followed by Ib (11/50 specimens, 22%), Ic (11/50 specimens, 22%), IIa (9/50 specimens, 18%), and Ia (4/50 specimens, 8%).

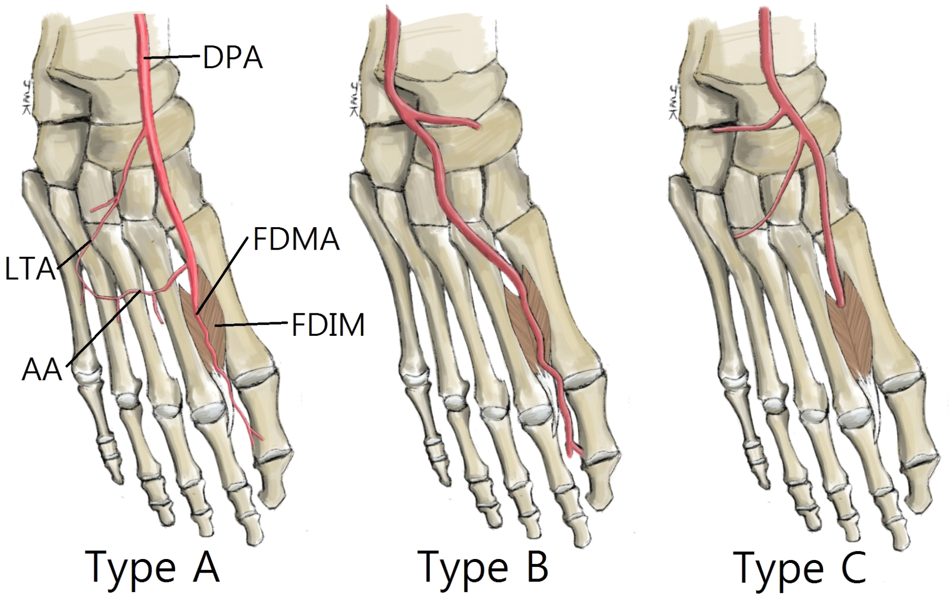

Fig. 1. Diagram showing the classification of the dorsalis pedis artery (DPA) according to its anatomic course. In type A the DPA runs to the medial one-third side of the foot, continuing on to become the first dorsal metatarsal artery (FDMA). In type B the DPA runs to the lateral one-third of the foot, and descends medially to the first dorsal interosseous space, becoming the FDMA. In type C the DPA runs to the medial one-third or middle one-third side of the foot, and runs below the first dorsal interosseous muscle (FDIM); the FDMA is absent in the anterior view. LTA, lateral tarsal artery; AA, arcuate artery.

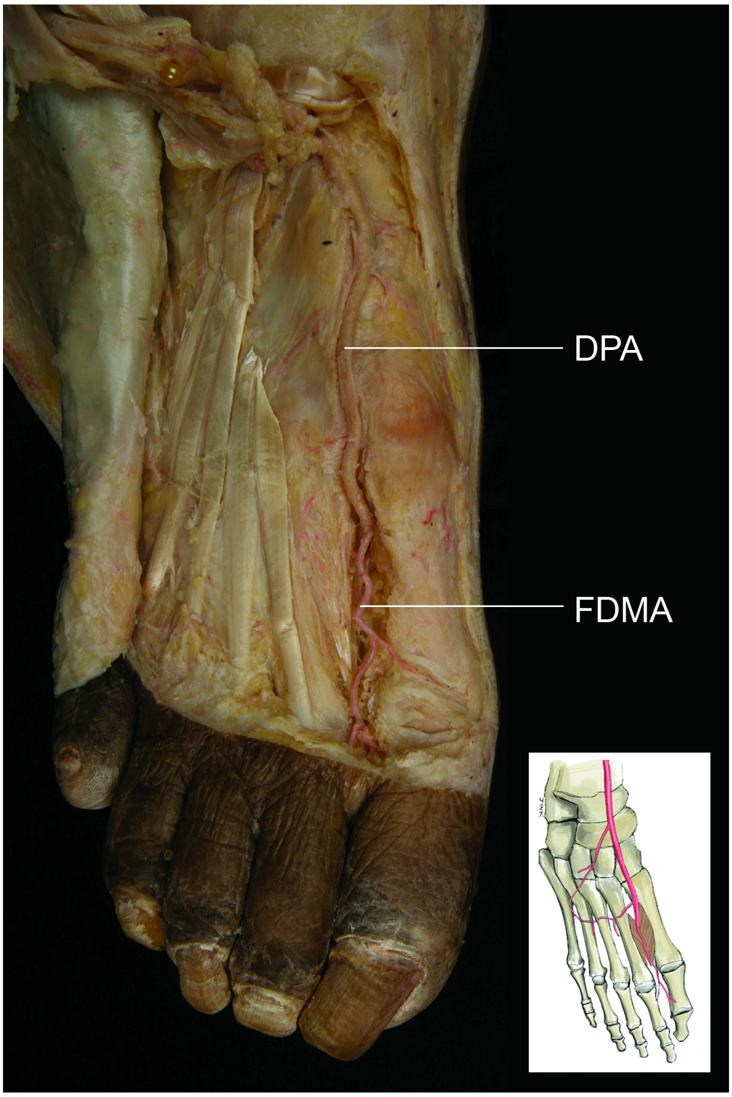

Fig. 2. Type I dorsalis pedis artery (DPA) and a type Ia first dorsal metatarsal artery (FDMA). The DPA continues to FDMA on mesial side. The extensor hallucis longus and brevis tendons were removed.

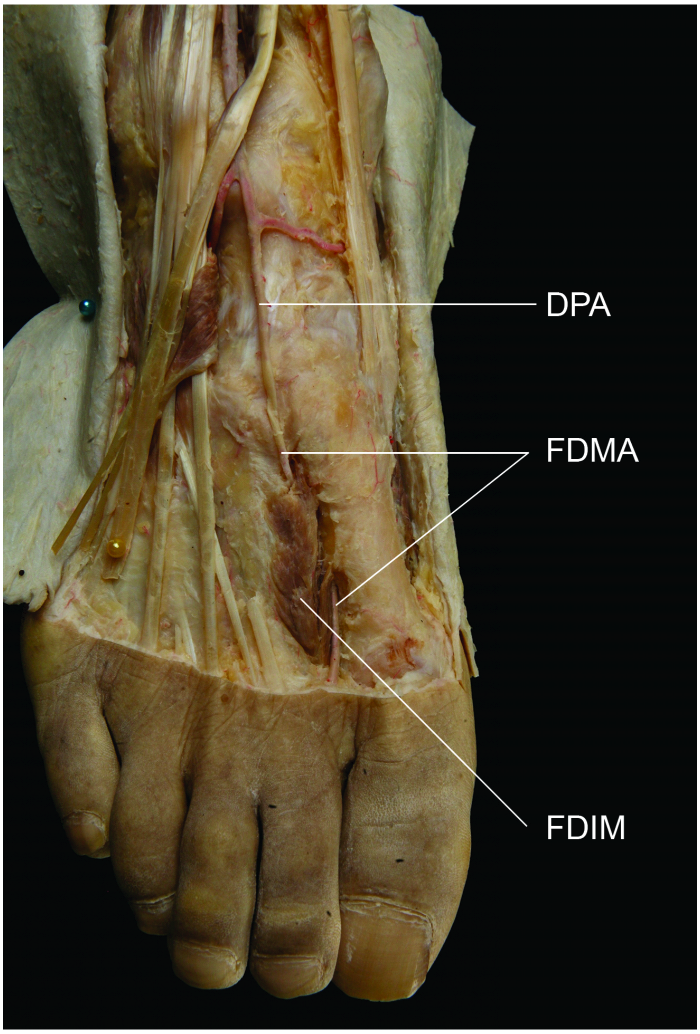

Fig. 3. Type I dorsalis pedis artery (DPA) and type Ib first dorsal metatarsal artery (FDMA). The FDMA runs obliquely below the first dorsal interosseous muscle (FDIM), reappearing superficially at the middle portion of the muscle. The extensor hallucis and brevis tendons were reflected to the lateral side.

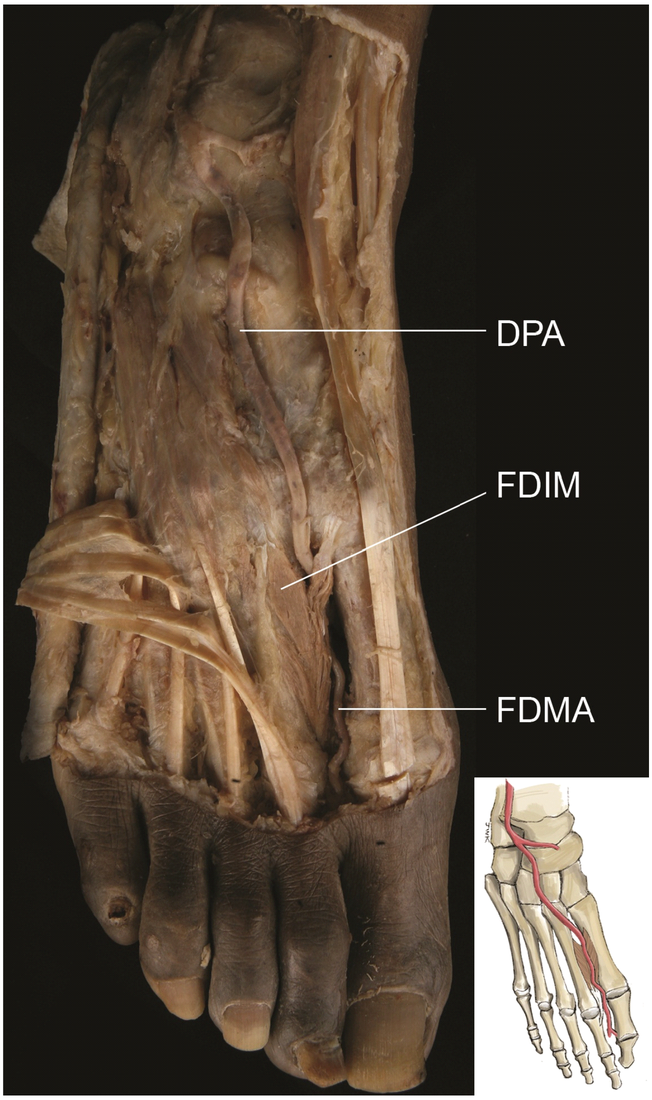

Fig. 4. Type II dorsalis pedis artery (DPA) and type Ib first dorsal metatarsal artery (FDMA). The DPA descends from the lateral side of the malleolus and forms the FDMA. The FDMA runs obliquely below the first dorsal interosseous muscle (FDIM) reappearing superficially at the middle portion of the muscle.

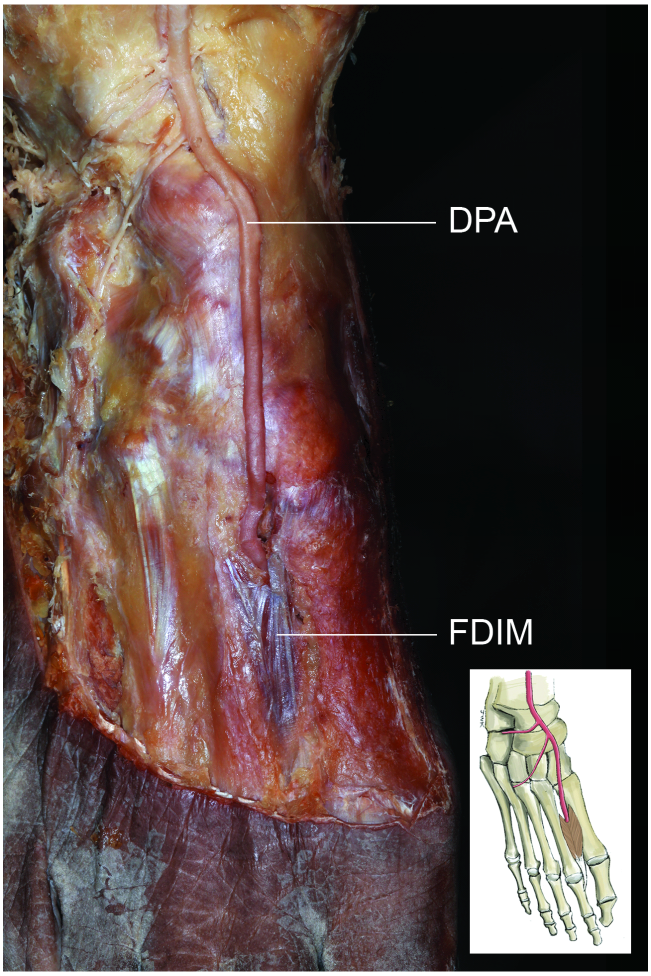

Fig. 5. Type III dorsalis pedis artery (DPA) and type III first dorsal metatarsal artery (FDMA). The DPA descends and runs into the first dorsal interosseous muscle (FDIM)

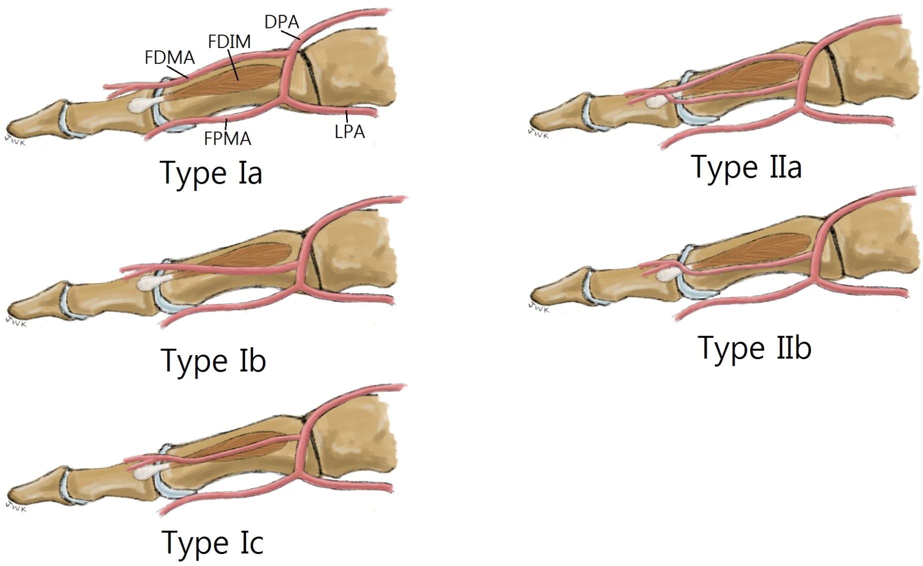

Fig. 6. Diagram showing coronal views of the first dorsal interosseous space and the classification of the first dorsal metatarsal artery (FDMA) according to its relationship with the first dorsal interosseous muscle (FDIM). In type Ia the FDMA runs above the FDIM. In type Ib the FDMA runs below the FDIM, then ascends obliquely above the muscle. In type Ic the FDMA runs in parallel with the FDIM. In type IIa the FDMA forms two branches that run below and above the FDIM. In type IIb FDMA runs below the FDIM. LPA, lateral plantar artery; FPMA, first plantar metatarsal artery.

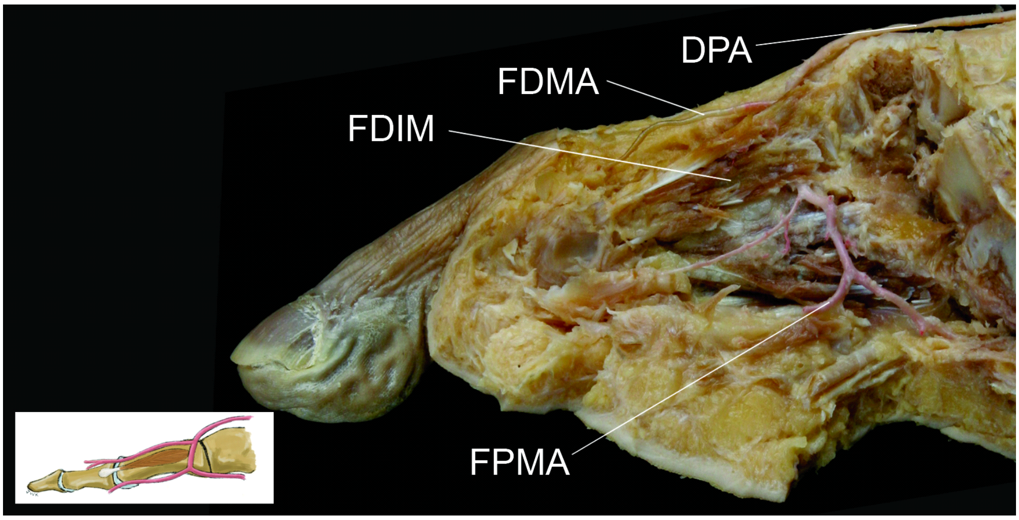

Fig. 7. Type Ia first dorsal metatarsal artery (FDMA). The second, third and fourth metatarsal bones were removed to allow a clear view. The dorsalis pedis artery (DPA) forms the FDMA above the first dorsal interosseous muscle (FDIM), as well as the first plantar metatarsal artery (FPMA) below the muscle.

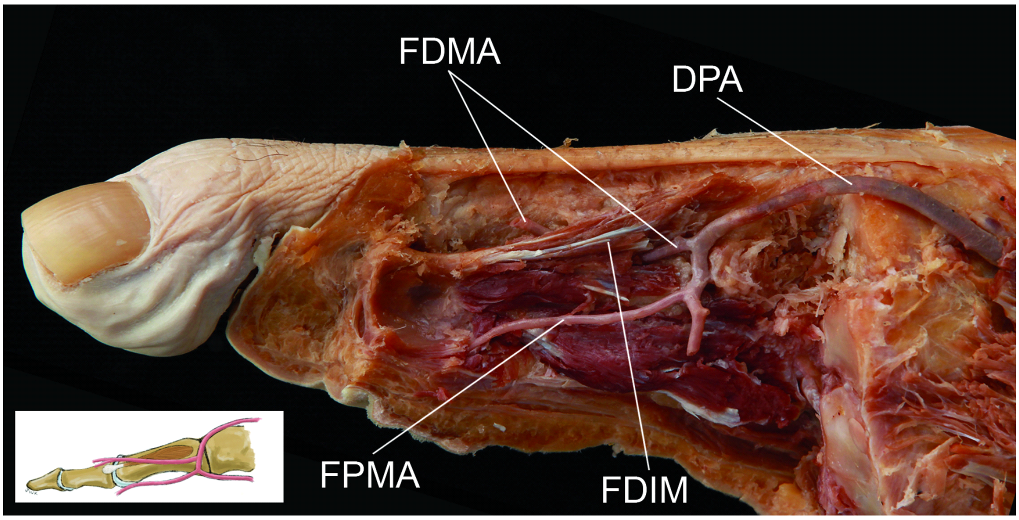

Fig. 8. Type Ib first dorsal metatarsal artery (FDMA). The artery runs below the first dorsal interosseous muscle (FDIM), and then passes through the muscle obliquely upwards and reappears superficially. DPA, dorsalis pedis artery; FPMA, first plantar metatarsal artery.

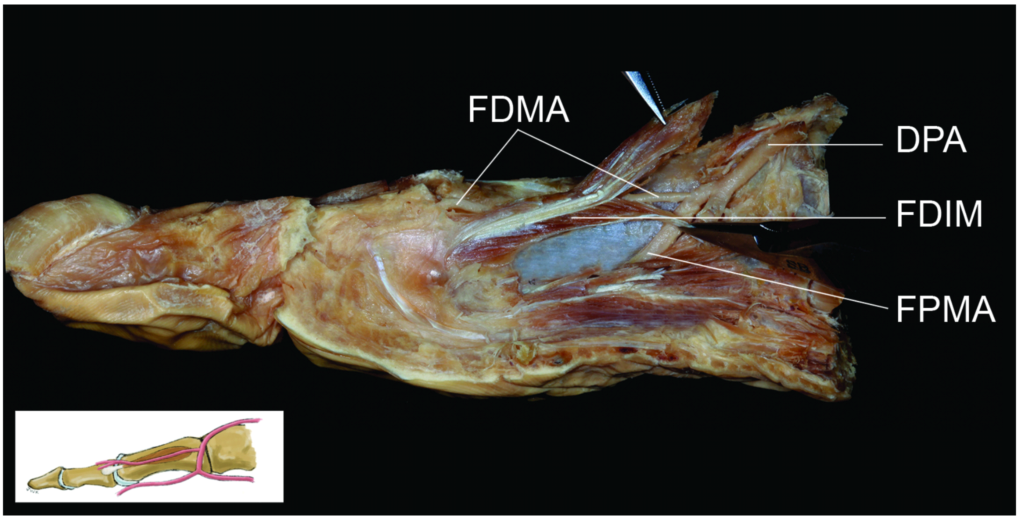

Fig. 9. Type Ic first dorsal metatarsal artery (FDMA). The FDMA runs parallel to the first dorsal interosseous muscle (FDIM), remaining inside it. DPA, dorsalis pedis artery; FPMA, first plantar metatarsal artery.

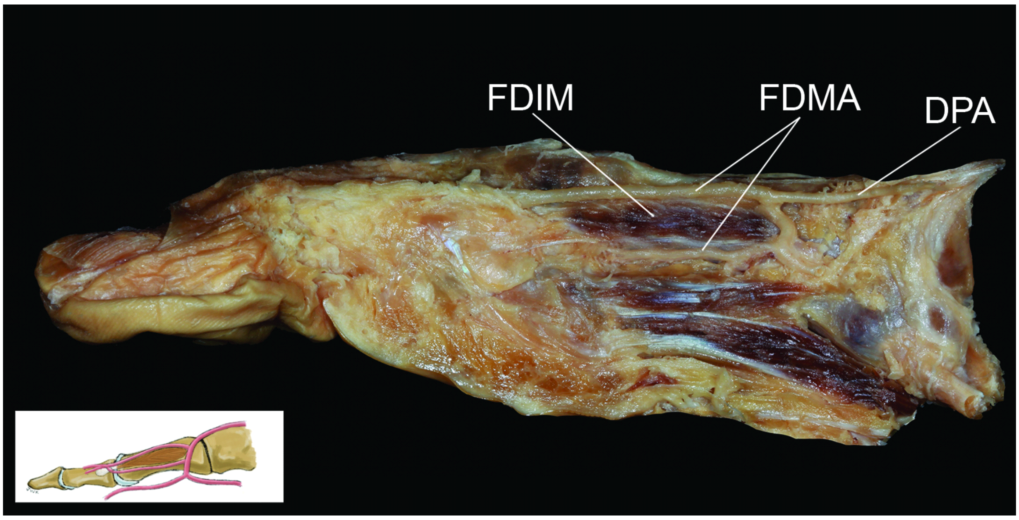

Fig. 10. Type IIa first dorsal metatarsal artery (FDMA). The dorsalis pedis artery (DPA) forms two branches of FDMA that run above and below the first dorsal interosseous muscle (FDIM).

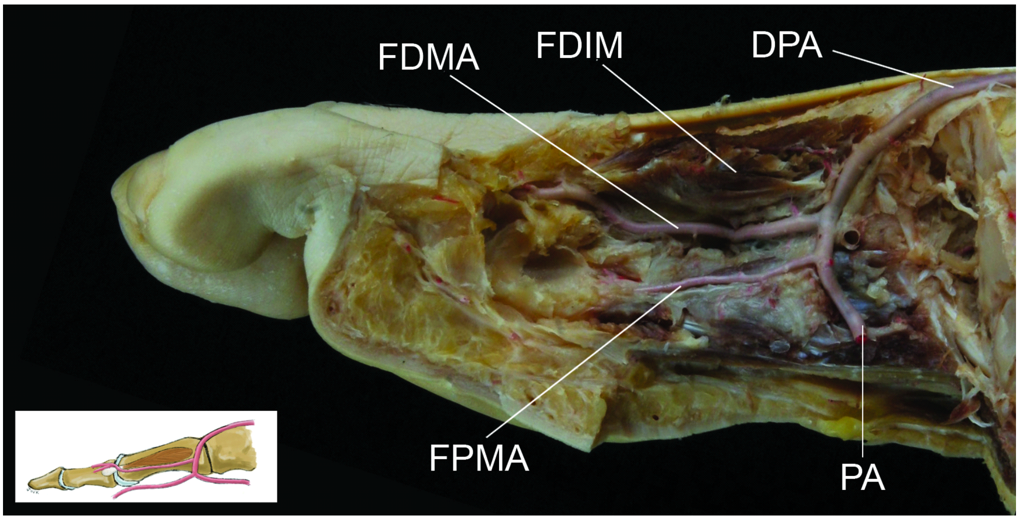

Fig. 11. Type IIb first dorsal metatarsal artery (FDMA). The FDMA runs below the first dorsal interosseous muscle (FDIM). DPA, dorsalis pedis artery; FPMA, first plantar metatarsal artery; PA, plantar arch.

3. Trabecular: cortical bone ratio (TBR)

TBR of the second metatarsal bone

The second metatarsal bone was divided in five parts, designated as regions 1-5, and the TBR was carculated in each part (Figs. 12, 13, Table 1). No trabecular bone was observed in regions 1 and 5, which were 10mm from the edges of the base and head, respectively, in any of the specimens. The TBR was thus calculated only for regions 2 - 4. The TBR appeared to be lower in region 3 (which was the middle of the body) than in regions 2 and 4, and was highest overall in region 2; however, the differences in the TBR between these three regions of the second metatarsal bone were not statistically significant (P>0.05).

Differences in the TBR between the sexes

There were no statistically significant differences in the TBR overall between the sexes (P>0.05, Table 2). The males tended to have a higher TBR in regions 2 and 3 than the females, while the females tended toward a higher TBR in region 4 than the males. In the males, the TBR in region 2 appeared to be higher than in region 4, while among the females the reverse was true.

Comparison of the TBR between age groups

The specimens were divided into the following three age groups: ≤69 years, 70-79 years, and ≥80 years (Table 3). The TBR did not differ significantly between these three age groups (P>0.05), but it tended to be highest in all regions among those aged ≥ 80 years, and to be higher in region 2 than in region 4 in all age groups.

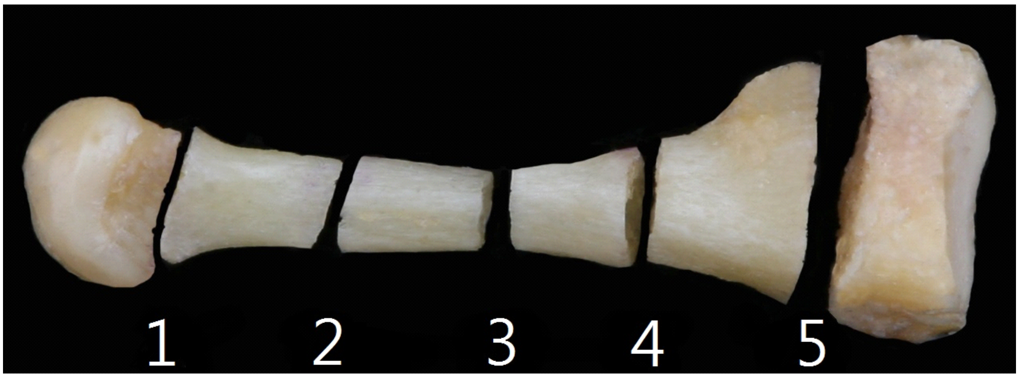

Fig. 12. The second metatarsal bone was removed from the dorsum of the foot, and sectioned with a disc on five planes: (1, 5), 10 mm internally away from the proximal (base) and distal (head) ends; (3), at the middle of the body; and (2, 4), 10 mm externally away from point 3.

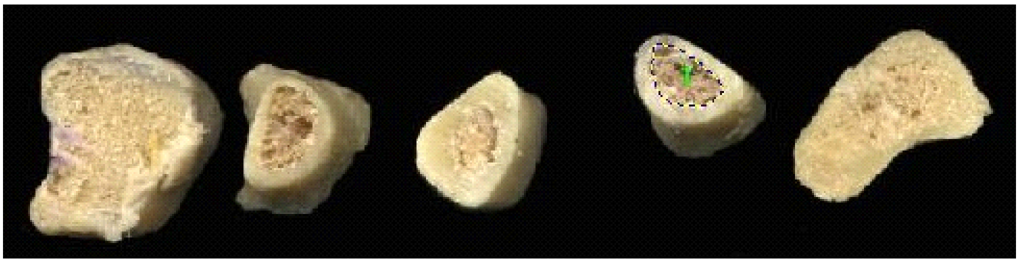

Fig. 13. Sectioned metatarsal bones were scanned with a photograph scanner, and the trabecular and cortical bone areas were calculated using image- analysis software.

Table 1. Trabecular: cortical bone ratio (TBR) of the second metatarsal bone.

Region	*N*	Mean	SD
1	24	0	0
2	24	35.6	7.7
3	24	28.3	6.5
4	24	31.6	9.2
5	24	0	0

Table 2. Comparison of the Trabecular: cortical bone ratio (TBR) between males and females.

Region	Males			Females		
	N	Mean	SD	*N*	Mean	SD
1	21	0	0	3	0	0
2	21	36.2	7.5	3	30.7	8.3
3	21	28.5	6	3	26.8	10.9
4	21	31.1	9.1	3	35.3	11.1
5	21	0	0	3	0	0

Table 3. Comparison of the trabecular: cortical bone ratio (TBR) among age groups.

Region	≤69 years			70-79 years			≥80 years		
	N	Mean	SD	*N*	Mean	SD	*N*	Mean	SD
1	6	0	0	11	0	0	7	0	0
2	6	37.2	4	11	32.8	9.6	7	38.4	5.9
3	6	28.5	6.6	11	25.8	5.9	7	32.2	6
4	6	33	9.8	11	28	7.9	7	36.1	9.6
5	6	0	0	11	0	0	7	0	0

Difference in the TBR between left and right sides

There were no significant differences in the TBR regardless of the region, between left and right (P>0.05, Table 4), although the mean TBR on the right side appeared to be higher than on the left in all regions. TBR was lowest in region 3 on both sides.

Table 4. Comparison of the trabecular: cortical bone ratio (TBR) between the left and right metatarsal bones.

Region	Left			Right		
	N	Mean	SD	*N*	Mean	SD
1	21	0	0	3	0	0
2	21	35.3	9.6	3	35.9	5
3	21	25.7	5.2	3	31.5	6.6
4	21	28.7	6.6	3	35	10.9
5	21	0	0	3	0	0

Ⅳ. DISCUSSION

The dorsalis pedis artery is the continuation of the anterior tibial artery, and arises from below the ankle joint. It runs down to the medial side of the extensor hallucis longus muscle, and then courses to the lateral side after passing the inferior extensor retinaculum, after which it passes below extensor hallucis brevis muscle. At this point it branches into the arcuate and lateral tarsal arteries, which enter the first dorsal interosseous space. Before connecting to the plantar arch, the first dorsal metatarsal artery divides from the dorsalis pedis artery, which runs below or above, passing through the first dorsal interosseous muscle. In the sole of the foot, the artery originates from the posterior tibial artery, forming the lateral and medial plantar arteries. The lateral plantar artery continues to the plantar arch below the adductor hallucis muscle, and gives off the plantar metatarsal arteries.

The anatomic variation of the course of the dorsalis pedis artery could be divided into just three patterns in this study. Previous studies have described between four and six variations in the course of this artery (Kang et al. 1984; Kim et al. 2001). These other studies included cases not included in the present study, such as when the first dorsal metatarsal artery did not form from the dorsalis pedis artery, or when the artery ran superficial to the deep fascia (Kim et al. 2001). By comparison, the missing divisions in the present study included the first dorsal metatarsal artery arising from the lateral tarsal artery and the posterior tibial artery, and absence of the first dorsal metatarsal artery (Kang et al. 1984). The dorsalis pedis artery was found mainly between extensor hallucis longus and brevis tendons, and gave off the first dorsal metatarsal artery. When the artery ran below the first dorsal interosseous muscle in this study, it was designated as type C. In the previous studies

(Kang et al. 1984; Kim et al. 2001), when the first dorsal metatarsal artery was not formed by the dorsalis pedis artery, the location was unclear. In both studies, the artery discontinued at the junction of the 1st dorsal interosseous muscle on proximal side, and it seemed logical to use the first dorsal interosseous muscle as the reference point.

In the present study, the most prevalent condition was type A, where the dorsalis pedis artery formed the first metatarsal artery in agreement with the previous studies (Kang et al. 1984; Kim et al. 2001; Chung et al. 1989). While types B and C were also observed, whereby the artery ran from the lateral side or was not given off by the first dorsal metatarsal artery, respectively. The total percentage of types B and C was lower than reported previously, and the prevalence of type C was slightly greater than type B, as also reported by Kim et al (2001). The lack of other patterns in this study is probably due to the small number of specimens examined, but it should also be noted that the other types are very rare. In addition, one specimen was not included in this study because the dorsalis pedis artery was not found. We believe that this specimen may have been equivalent to type VI in the study of Kim et al. (2001).

The anatomic variations of the first dorsal metatarsal artery were also confirmed herein. The most common type in relation to the interosseous muscle was type I, and among which type Ib was most the common. The first dorsal metatarsal artery was also divided in various types in previous studies (Nam et al. 1996; Tark et al. 1996; Kim et al. 2001; Chung et al. 1989). All of the previous studies, with the exception of that of Kim et al. (2001), divided the first dorsal metatarsal artery into five types, with subtypes Ia and Ib, IIa and IIb, and III.

In type Ib, the artery ran through the first dorsal interosseous muscle. In the study by Kim et al, type I was divided into type Ib and Ic, in which the artery ran through the muscle either obliquely or in parallel with the muscle fibers, respectively (Kim et al. 2001). We also found many cases of types Ib and Ic. Interestingly, type Ia was the least common. In previous studies, type I appeared to outnumber type II by a factor of three. However, in the present study, the relative proportions of types I (52%) and II (48%) were, very similar. This is probably due to us being able to dissect the specimen with a clearer view than perhaps has been possible previously, by removing the second, third, and fourth metatarsal bones.

The type III pattern was not found in the study by Chung et al (Chung et al. 1989), as in the present study; we were unable to find any specimens in which the first dorsal metatarsal artery was so small that it could not be used in flap formation. It is possible to confuse types I and III, however, we were able to locate arteries with diameters of at least 1.5mm.

In the other studies (Nam et al. 1994; Tark et al. 1996; Kim et al. 2001; Chung et al. 1989), type IIa was designated if the artery formed two branches that ran above and below the muscle, and the diameter of the upper artery was thinner than the lower artery. However, in the present study the diameters of the branches of type IIa arteries were the same.

Before the harvesting surgery, the first dorsal metatarsal artery can be located using Allen's test and Doppler flowmetry. Various other techniques, such as arteriography are also useful. However, predicting the location before surgery could be easily done by having a clear understanding regarding the possible anatomic variations. In most cases the artery run on the medial side of the foot below the extensor retinaculum (type A), and it is generally located between the extensor hallucis longus and extensor hallucis brevis tendons, continuously forming the first dorsal metatarsal artery, either superficially or inside the first dorsal interosseous muscle. Harvesting a flap in cases of type IIb and III first dorsal metatarsal arteries is impossible, and in such cases the surgeon will need to search for a different location or method (Kim et al. 2011). With regard to the dissection technique, it is essential to ensure the continuity of the dorsalis pedis artery to the first metatarsal artery (Banis et al. 1988). From this viewpoint, the type A dorsalis pedis artery and first metatarsal artery would be the preferred anatomic types, since in these types, the first dorsal interosseous muscle would not be damaged; that muscle plays an important role in the rigidity of the foot via a stabilizing mechanism, it would be proper to not to interfere with the muscle structure (Kalin et al. 1987). The diameter of the dorsalis pedis artery is about 1.5 - 2 mm, which is ideal for successful microvascular anastomosis (Ben-Hur et al. 1980). In the present study, the artery was sufficient thick to allow it to be easily located.

The TBR of the second metatarsal bone was also investigated in this study. Other studies have found (Azevedo et al. 2010) that this bone could be used for reconstruction of the anterior mandible, and even the nose and the ascending ramus (Kim et al. 1995). However, the findings of the present study suggest that second metatarsal bone is unsuitable for reconstruction of defects in the main body of the mandible, even for placement of an implant with a size of 5 mm X 8 mm. Given the requirement of withstanding masticatory forces, and for the sake of graft stability, the present findings suggest that the second metatarsal bone should be used only for case of defects in the marginal mandibular bone, and not when replacement of the whole mandibular body is necessary.

The second metatarsal bones were sectioned in five regions to evaluate its suitability for grafting with implants. This is the first study to evaluate the TBR of second metatarsal bone. After removal of a mandibular tumor and the subsequent performance of a graft procedure, an implant-supported prosthesis could be selected as the next treatment plan. It is therefore logical to study the quality of the bone of the second metatarsals.

The head and base parts of the second metatarsal bone are very rigid, and comprise 100% cortical bone; trabecular bone was found in the regions 2 – 4. The lower TBR in the middle region indicates that the body part is the thinnest portion of the entire metatarsal bone, and so the TBR should be lower than in the other parts. Together with the other bones, ligaments, and muscles of the foot, the second metatarsal bone plays an important role in the support of the whole body and stabilization of its movements. Therefore, it is more than understandable that the toughness of the second metatarsal bone is at least equivalent to that of the mandible, which is under constant stress of the masticatory muscles and bite forces. An interesting finding was that the TBR of regions 2 – 4 was similar to that found for the mandible in a previous study (Won et al. 2010). In particular, it was similar to the canine, first premolar, second premolar, and first molar regions of the dentate mandible, and the lateral incisor to second molar regions in the edentulous mandible. The bone in the mandible is mostly type D2 or D3, and the pattern of that bone is similar to that in the body part of the second metatarsal bones. Therefore similar drilling procedure can be used for implant placement than that usually used for the mandible.

The success of the implant increases with the presence of dense trabecular bone and thicker cortical bone (Misch et al. 2008). D1 bone has fewer blood vessels, and therefore delicate and minimal reflection is recommended, since its blood supply is mostly from the periosteum. Type D2 bone has a dense to porous cortical crest, and inner trabecular bone is coarse (Misch et al. 2008). In most cases the bone in the middle two-thirds of the second metatarsal bones was type D2, while that at the epiphyseal ends was type D1. Care must be taken when placing the implant, not to overheat the bone, as this is almost 100% cortical bone at those locations. The widest final drilling, and tapping and crestal bone drilling must be conducted before fixture placement. However, when placing a fixture into the middle of the bone, bicortical fixation could be performed, but the surgeon should remember not to penetrate the entire bone. If placed on the symphysis side, it may be possible to place an implant-supported overdenture, or even 10 mm long implant.

The TBR did not differ significantly between males and females. Although the males appeared to have a higher TBR in regions 2 and 3 than the females, while the females had a higher TBR in region 4. However, the lack of statistical significance may not have a clinical meaning because of the difference in the number of specimens for each gender. The higher values in regions 2 and 3 could be due to males being generally bigger than females, and thus the size of the metatarsal bones should be also bigger, increasing the TBR ratio. Factors such as hormonal changes could also affect the TBR in females, but did not appear to affect the results in this study (Kim et al. 2011).

While the TBR did not differ significantly among the three age groups, an interesting change in the TBR was noted; the TBR appeared to be highest in the oldest age group. This could be explaned by the hormonal changes in the older age groups, such that more trabecular bone is formed than cortical bone. In addition, older people exercise less, leading to a reduction in the toughness of the bones. It is possible that, overheating of the bone could therefore be less of a problem in older age groups during the drilling procedure for the implant placement, but at the same time, the failure rate might increase because of the lesser initial stability. Therefore, completely submerging the implant below the crest level should be considered.

Comparison of the left and right sides revealed a higher mean TBR in all regions on the right side. Although the total number of specimens was very small, the higher TBR might be explained by most people using their right foot more than their left foot, since most people are right-side dominant. It is a common sense that the power of the body on left and right sides will be different, with the right metatarsal bone likely to be bigger than that on the left. Differences in the sizes, and shape of the second metatarsal bone were observed, between specimens, and even on the left and right sides.

The success of a graft formed using the dorsalis pedis flap requires not only a skilled surgeon, but also a detaild understanding of the possible anatomic variations of the course of the dorsalis pedis and first metatarsal arteries, and of the TBR of the second metatarsal bone. This is the first study to demonstrate that the second metatarsal bone is suitable for receiving implants. In addition, the superficial peroneal nerve and superficial venous system must also be considered during harvesting, and after placing the graft, sufficient attached gingiva and right vestibular depth should be ensured for a better implant-supported prosthesis outcome.

Ⅴ. CONCLUSION

The conclusions of this study are as follows.

1. Three types of dorsalis pedis artery were found, and the majority were type A (94.1%), in which the artery is formed directly from the first dorsal metatarsal artery. The next most common was type C (3.9%), in which the artery ran below the first dorsal interosseous muscle and did not reappear as the first dorsal metatarsal artery, in the anterior view. Finally, the least prevalent was type B (1.9%), in which the artery ran laterally and formed the first dorsal metatarsal artery.

2. Five types of first dorsal metatarsal artery were found. For type Ia (8%), the first dorsal metatarsal artery ran above the first dorsal interosseous muscle, for type Ib (22%), the artery ran through the muscle obliquely, for type Ic (22%), the artery ran through the muscle in parallel with the muscle fibers. For type IIa (18%), the artery formed two branches that ran above and below the muscle, and the branches were of equal diameter, and for type IIb (30%), the artery ran below the muscle.

3, All regions of the second metatarsal bone appear to be suitable for receiving implants, but when placing the implant in the proximal ends, care should be taken not to overheat the bone because comprises type D1. placing the implant near to the body part is recommended, but that area is the thinnest portion of the bone, and so only short implants should be placed there.

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Abstract (in korean)

하악골 재건을 위한 발등동맥, 제 1발허리동맥과 제 2발허리뼈의 해부학적 연구

<지도교수 허 경 석>

연세대학교 대학원 치의학과

김 재 원

발등동맥 피판은 현재 그것의 다능성과 효율성 때문에 널리 이용되고 있다. 발등동맥의 해부학적 위치에 대한 완전한 이해와 그것의 제 1발허리 동맥으로 이어지는 연속성은 피판의 성공과 생존을 위해 필수적이다. 하지만, 발등동맥과 제 1발허리동맥의 해부학적인 위치는 개개인간 큰 차이가 있다. 발등동맥 피판에서 골피부 피판을 형성하는것도 가능하나, 그들의 해부학적 형태와 해면골: 피질골 골 비율 (TBR) 을 조사했던 연구는 없었다. 이 연구의 목적은 발등동맥과 제 1발허리동맥의 해부학적 변이성을 시신 해부를 통해 명확히 하고, 제 2발허리뼈의 TBR 을 밝혀 임플란트에 대한 적합성을 보는 것이였다. 52개의 표본이 연구를 위해 준비되었다. 각 표본은 발등동맥을 찾기 위해 등쪽면에서 해부되었다. 발은 시상면에서 절단었으며, 두 번째, 세 번째, 네 번째 발허리뼈는 제 1발허리동맥의 경로와 제 1 등쪽뼈사이근과의 관계를 밝히기 위해 제거되었다. 제 2발허리뼈는 총 5면에서 절단되었으며 스캐너로 스캔되었으며, TBR 은 이미지 분석 소프트웨어를 이용하여 계산되었다. 데이터는 ANOVA 와 대응표본 t검증을 통해 통계적으로 정리되었다. 세 종류의 발등동맥을 찾을 수 있었다: (1) type A 가 제일 흔하였으며 (94.1%), 동맥이 연속적으로 제1발허리동맥으로 이어졌다. (2) 다음은 type C 였으며 (3.9%), 동맥이 제 1 등쪽뼈사이근 하방으로 주행하였다. (3) type B (1.9%)의 경우, 동맥은 측방으로 주행하였다. 제1발허리동맥의 다섯가지 종류를 찾을 수 있었다: Ia-c, 그리고 IIa 와 b

였다. 제일 흔한 타입은 type IIb (30%) 였으며, 이것은 동맥이 제1 등쪽뼈사이근 하방으로 주행하였으며, 이어서 type Ib (22%), 이것은 동맥이 근육속을 비스듬하게 주행하였으며, type Ic (22%) 는 동맥이 근육을 평행하게 주행하였다. IIa (18%)의 경우, 동맥이 근육 상방과 하방으로 주행하였으며, type Ia (8%)의 경우 동맥이 근육 상방으로만 주행하였다. 제 2발허리뼈는 5개의 파트로 나누어졌으며 (1-5), 모든 파트에서 TBR 을 계산하였다. 어떠한 표본에서도 head 와 base에서 10mm 안쪽으로 떨어진 1 과 5 구역에서는 해면골이 없었다. 구역 3 (body 의 가운데부분) 에서는 TBR 이 구역 2와 4에 비해 적은 것으로 나타났으며, 제일 높은 곳은 구역 2였다. 하지만, 그 차이는 통계적으로 유의성이 없었다 (P>0.05). 제2발허리뼈의 모든 구역은 임플란트를 식립하기에 적합하였으나, 골의 각 끝부위에 식립할 경우에는, 골에 과도한 열이 가해지지 않도록 노력해야 하며 가운데 부위에 식립할 경우에는 천공을 주의하여야 한다.

핵심되는 말 : 발등동맥, 제 1발허리동맥, 제2 발허리뼈, 제 1등쪽뼈사이근, 해면골 비율, 임플란트수술